# Z(ee) + ≥n Jets Cross Section

- Overview (Samples, selection criteria, ...)
- Corrections (EM, Trigger, Tracking, ...)
- Data vs MC comparisons
- Cross section unsmearing
- Z(ee) + ≥n Jets cross sections
- Systematics
- Summary

# Samples

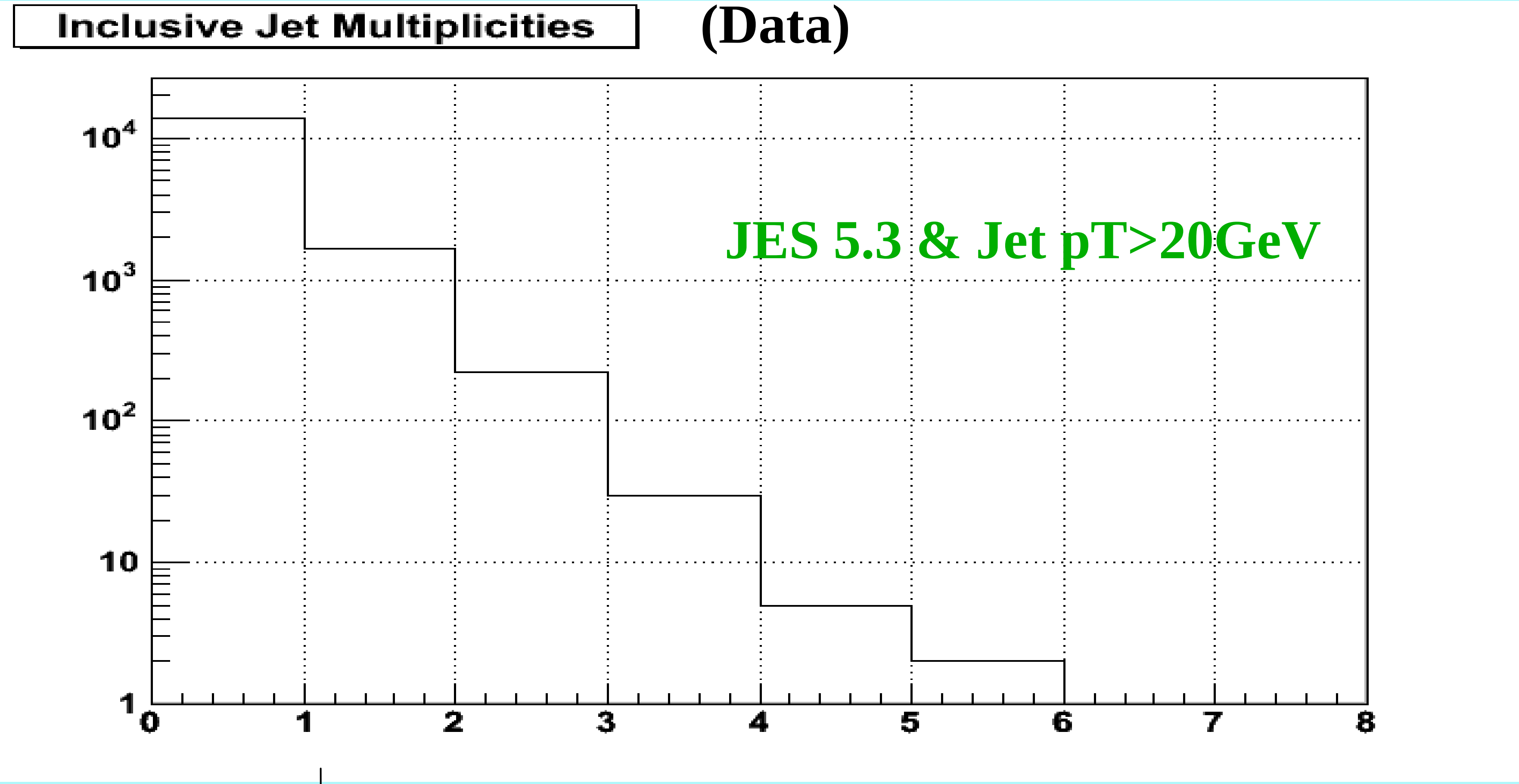
- **Data**:
  - Lumi = 343 $pb^{-1}$
  - Run range: 20 April 2002 - 28 June 2004 (Runs 151,817 - 194,566)
  - Pass 2 (T42 enabled)
  - JES 5.3
  - EM1TRK skim
  - Single EM triggers
  - Rejecting bad runs (CAL, SMT, CFT, Jet/Met, Lumi)
  - Processed with ATHENA (p16-br-03)

- **MC:**
  - Z/Gamma* –> $e^+e^-$ +X: 400k Pythia
  - Zj -> eej: 150k Alpgen + Pythia
  - Zjj -> eejj: 180k Alpgen + Pythia
  - Zjjj -> eejjj: 15k Alpgen + Pythia
  - Processed with ATHENA (p16-br-03)

# Selection Criteria

- Removing bad runs/LBNs & duplicate events
- PVX cut: |z|<60cm
- Using unprescaled single EM triggers
- Electron selection:
  - |ID|=10,11
  - EMF>0.9
  - Iso<0.15
  - HMx(7)<12
  - $p_T$>25GeV
  - |det_eta|<1.1
  - Including phi cracks
- Z selection:
  - 75GeV < $M_{ee}$ < 105GeV
  - At least one track-matched electron
  - At least one electron needs to fire the trigger
- Jet selection:
  - 0.05 < EMF < 0.95
  - HotF < 10
  - N90>1
  - CHF<0.4
  - L1conf
  - JES corrected $p_T$>20GeV
  - |phys_eta|<2.5
  - Removal of jets overlapping with electrons from Z within dR of 0.4

# Jet Multiplicities



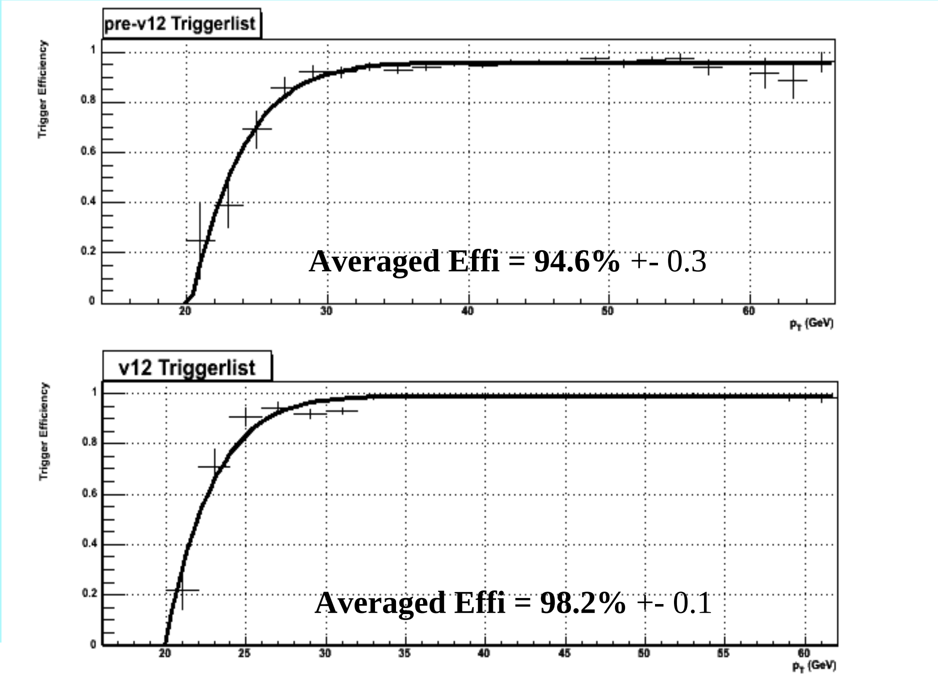

| Inclusive # of jets | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| # events (uncorr) | 13,893 | 1,646 | 219 | 30 | 5 | 2 |

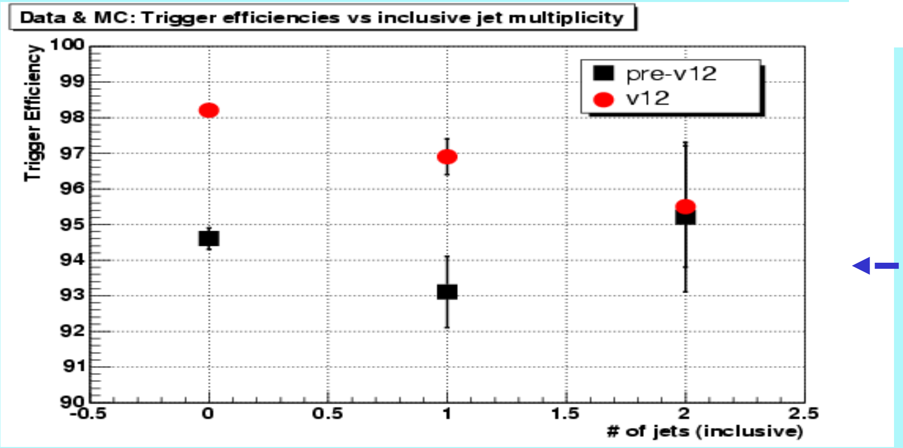
# Corrections

- Trigger
- EM Reco and ID
- EM-Track Match
- Acceptance
- Jet Reco and ID

# Trigger Correction

- Method: tag-and-probe method, where the probe electron is tested for matching trigger objects at L1, L2 and L3
- Need to separate trigger efficiencies for pre-v12 and v12 data
- No big variations in overall trigger efficiencies vs jet multiplicity are observed
- Applying trigger efficiency vs pt as corrections (weights) to all jet multiplicity samples

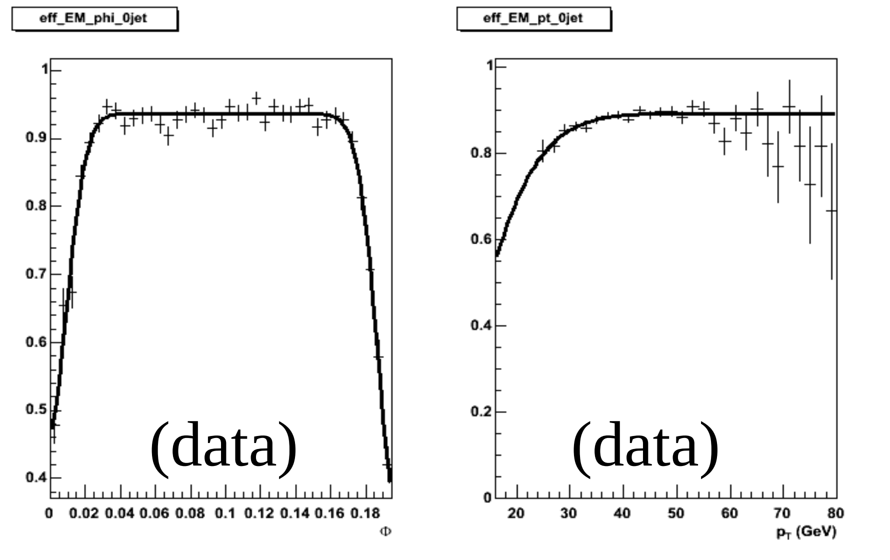


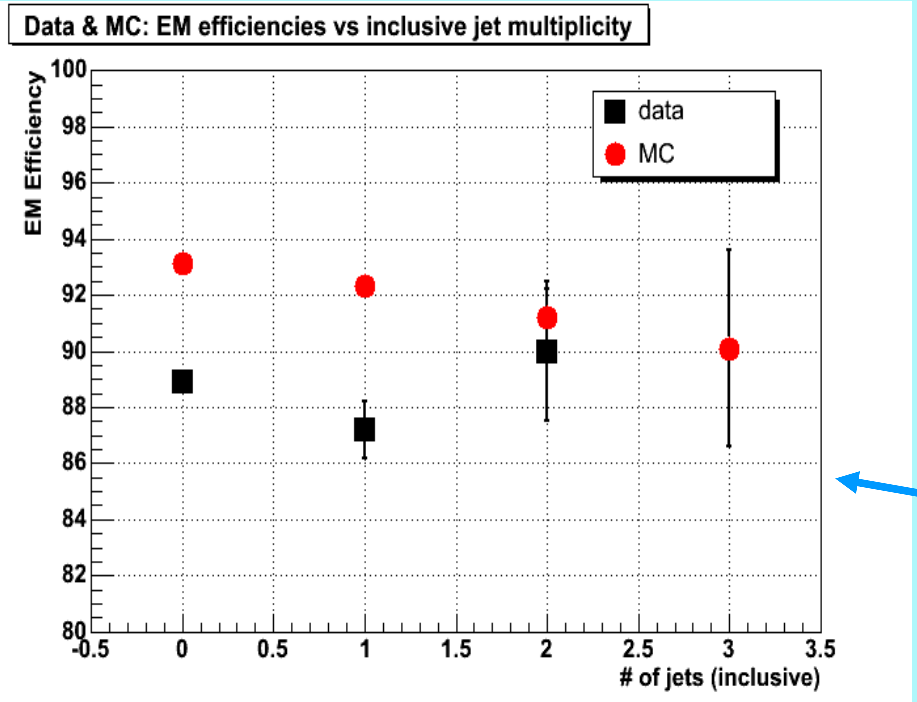




Overall trigger efficiency variation
vs
jet multiplicity

# EM Reco/ID Correction

- Using a tag-and-probe method: tag = tight electron, probe = track
- We derive parameterized (vs pT and Phi) efficiencies for Z(ee)+X sample



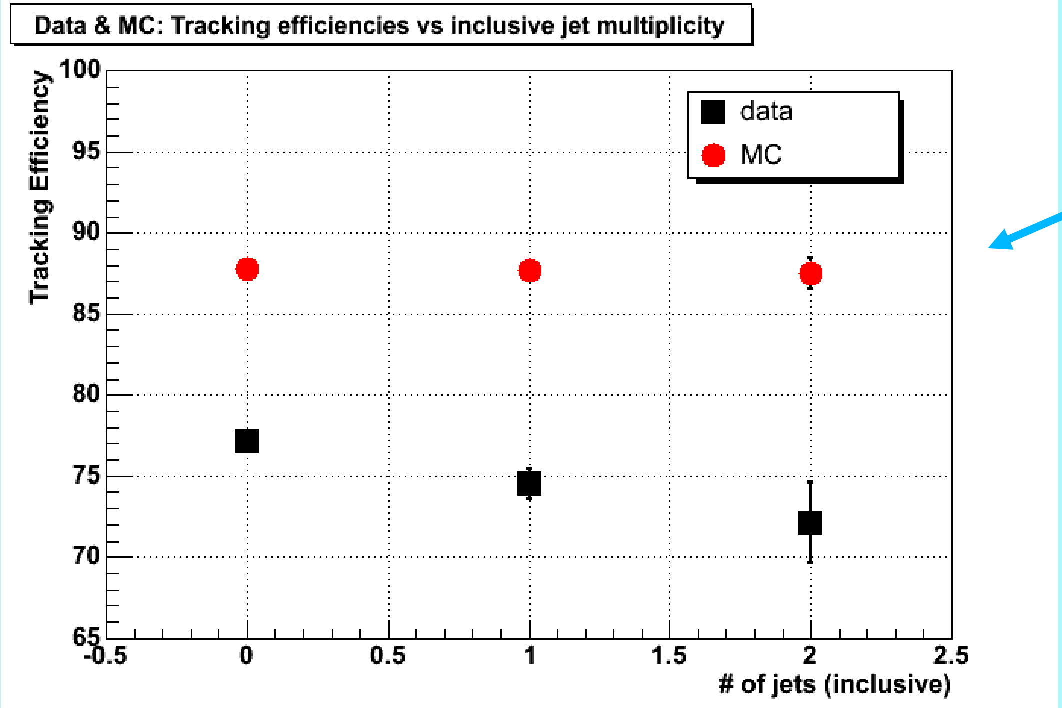




- We apply the parameterized efficiency curves as corrections (weights) to all jet multiplicity samples in data

# EM-Track Match Correction

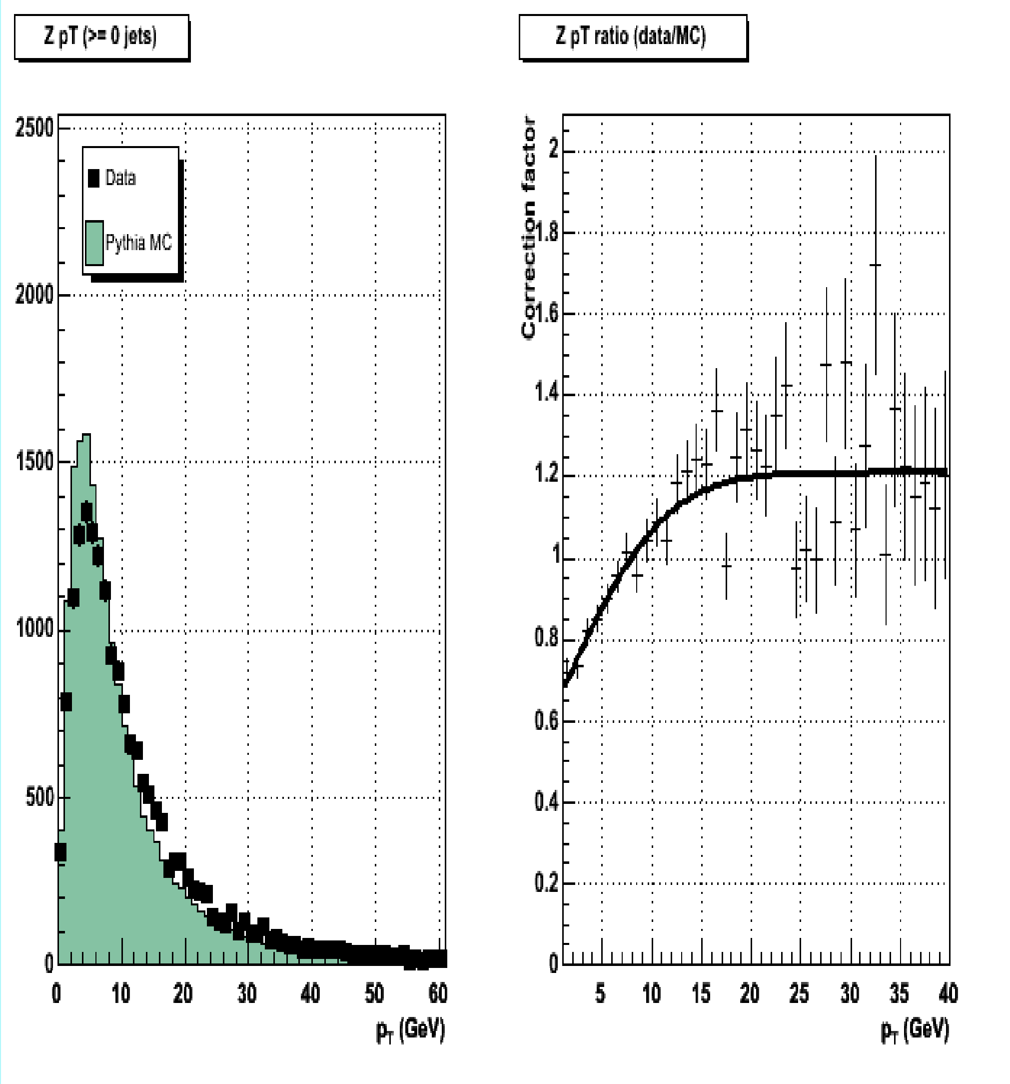
- Method:
  - # of signal events in $M_{ee}$ histogram when requiring 1 track match
  - # of signal events in $M_{ee}$ histogram when requiring 2 track matches
  - Take the ratio to get an averaged efficiency

- MC: Applying the averaged efficiency from 0-jet sample as corrections (weights) to all other jet multiplicity samples
- Data: Applying 0-jet, 1-jet, 2-jet values to the respective jet multiplicity samples and using 2-jet values for 3, 4, 5 jet samples



# Z pT Correction

- Needed to adjust Pythia inclusive Z MC to data
- After applying all the previous corrections we compare the Z pT between data and inclusive-Z MC
- We take the ratio of data over MC and apply it as an additional correction to the Pythia MC
- Not needed for Alpgen Z+jets samples



# Acceptance Correction

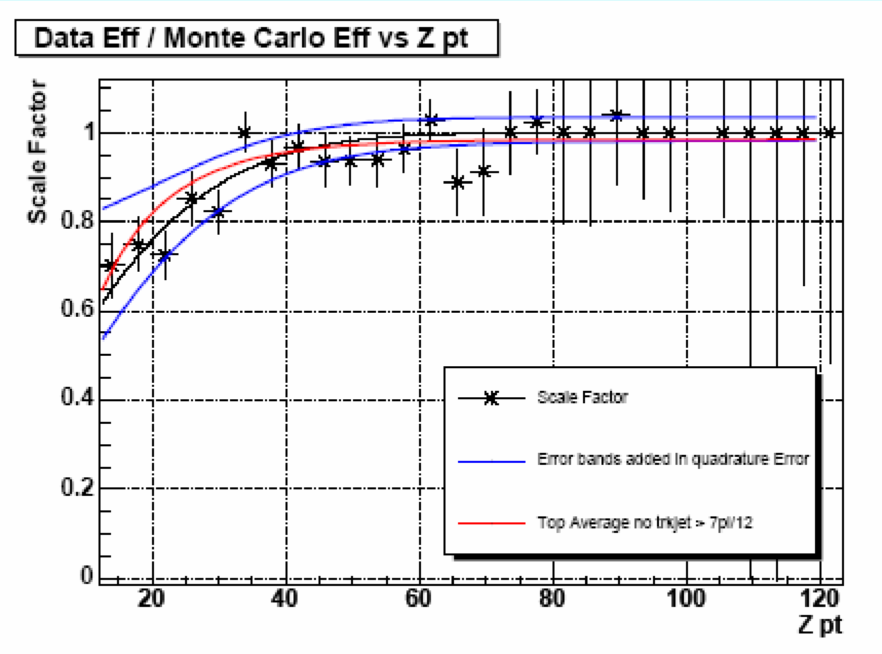
- Kinematic and geometric efficiency for Z's
  - |PVZ|<60cm
  - 2 electrons with pT>25GeV, |det_eta|<1.1
  - 75GeV < $M_{ee}$ < 105GeV
- Vs jet multiplicity based on the number of p.l jets with pT>20GeV, det_eta<2.5

$$\text{Acc} = \frac{\#\text{ of CAL Z's with n p.l. Jets (pT>20, |eta|<2.5)}}{\#\text{ of p.l. Z's with n p.l. jets (pT>20, |eta|<2.5)}}$$

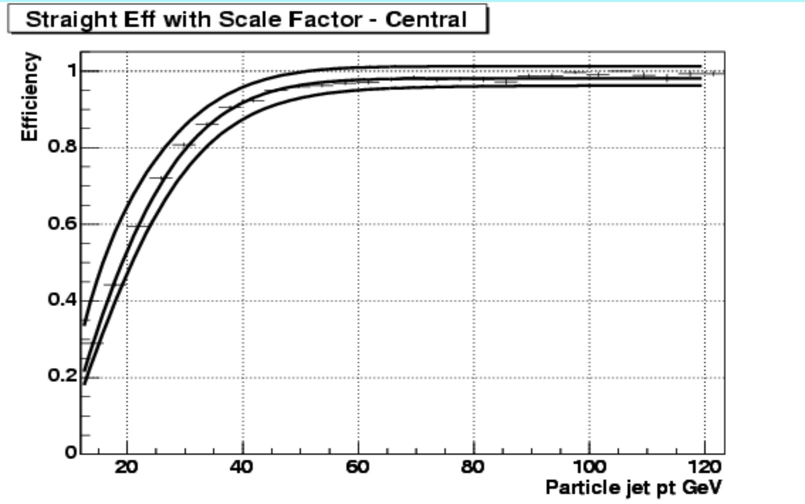
| Jetmult | Acceptance |
|---|---|
| 0 | 21.4%±0.1% |
| 1 | 25.1%±0.2% |
| 2 | 25.4%±0.2% |
| 3 | 27.4%±0.3% |
| 4 | 28.5%±0.7% |
| 5 | 30.3%±1.9% |

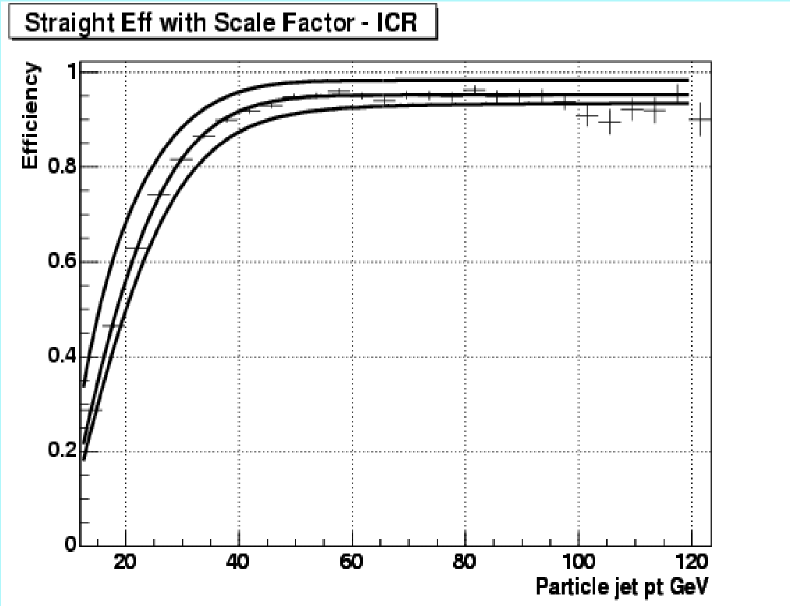
# Jet Reco/ID Correction (1)

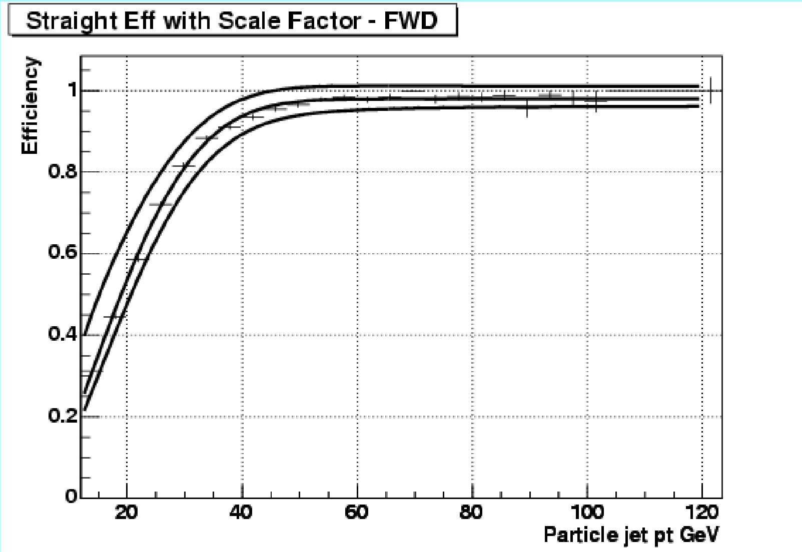
- Based on work done by **James Heinmiller**
- Deriving scaling factor using the Z pT method:
  - Looking for a jet recoiling against a Z boson (opposite in Phi)
  - Using Z pT method in both data and MC and taking ratio yields a scaling factor
- Estimating jet reco/ID efficiency in MC:
  - Matching particle level jets with CAL jets ($\Delta R=0.4$)
  - Parameterized vs smeared particle jet pT (data resolution smearing)
- We adjust the MC jet reco/ID efficiency with the scaling factor to match the data



# Jet Reco/ID Correction (2)



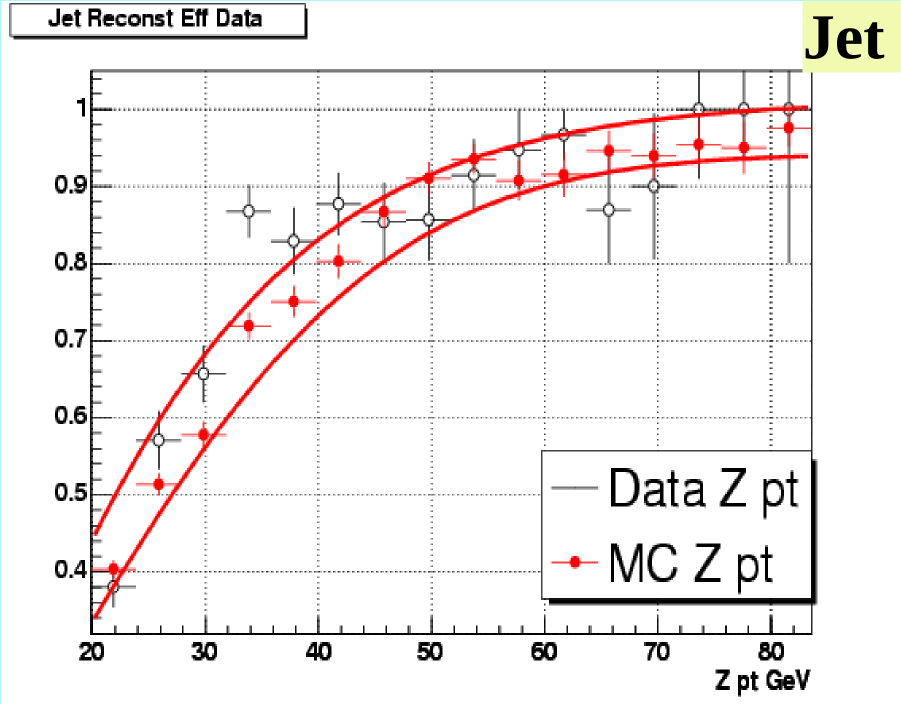




- Jet reco/ID efficiencies vs smeared particle-jet pt with errors (statistical, MET cut, event generator)
- Detailed note is in preparation

# Jet Reco/ID Correction (3)

Comparison of the probability of finding a jet recoiling against a Z vs Z Pt in data and particle level MC (PYTHIA).

- The particle jets have been smeared with the data jet energy resolutions
- The measured jet reco/id efficiency has been applied to particle jets (by dropping jets based on their Pt)
- Both data and MC have minimum jet pt of 8 GeV




**Jet Reco/Id closure test**

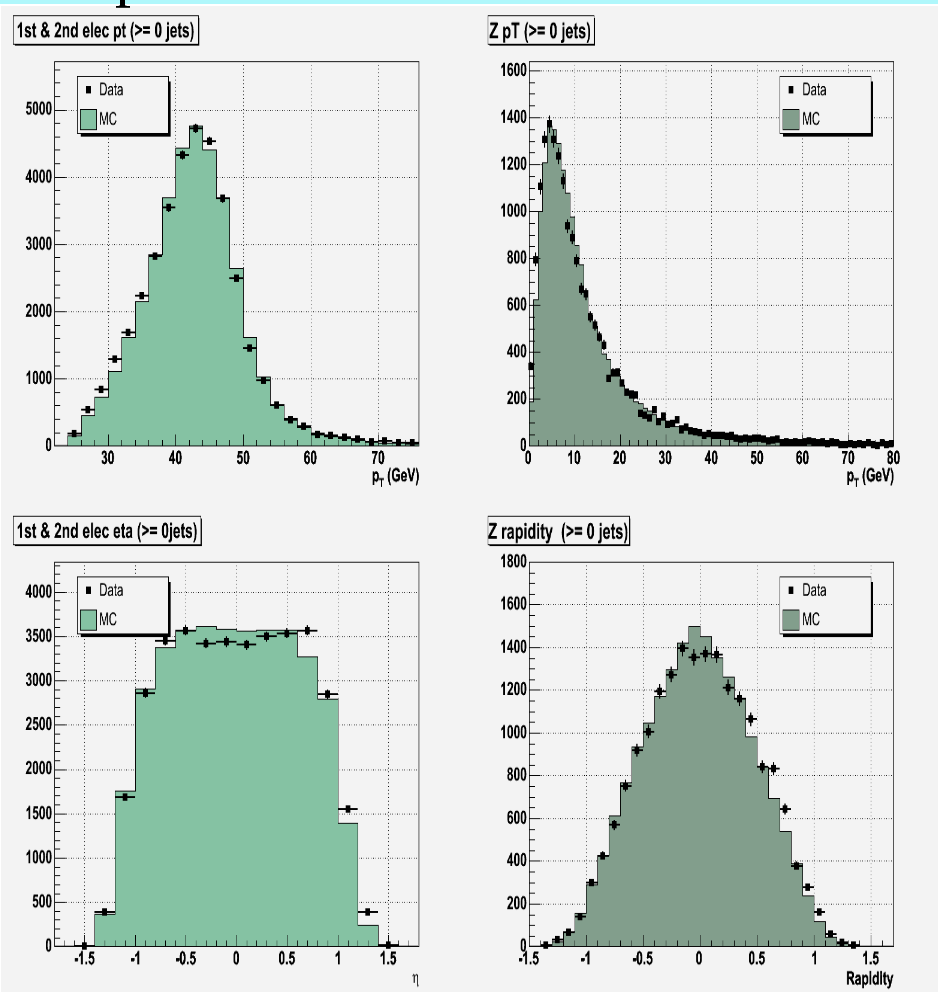
# Data vs MC

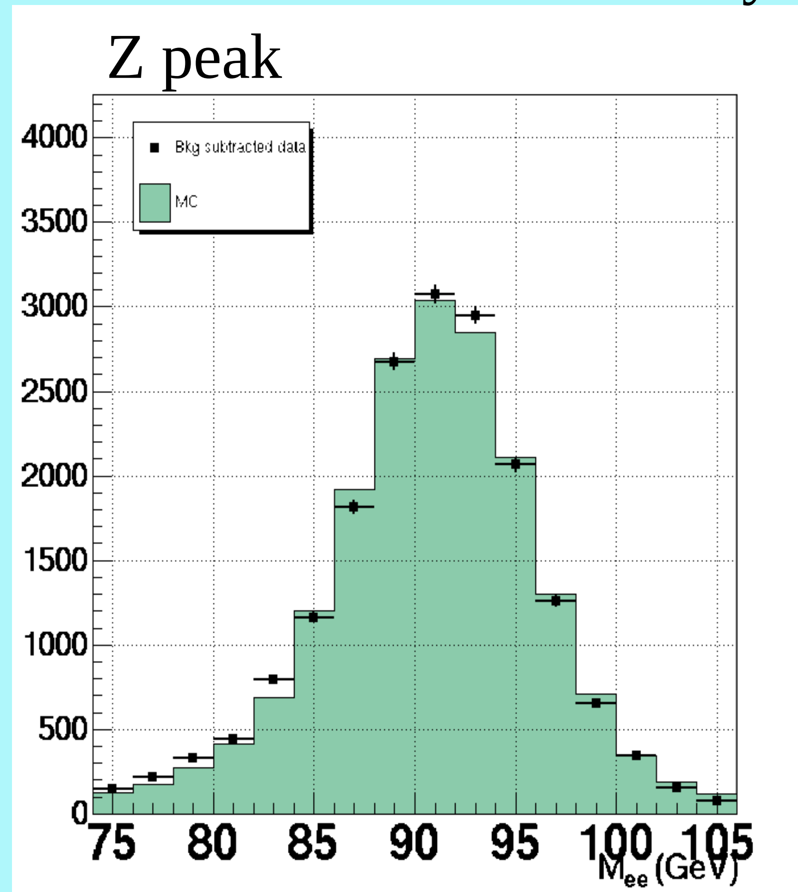
- Applying corrections: EM, Trigger, Tracking, Z pT, Jet Reco scaling
- Normalized wrt area

# Z(ee)+X: Electrons and Zs

Sample size ≈ 14k events

MC = Pythia



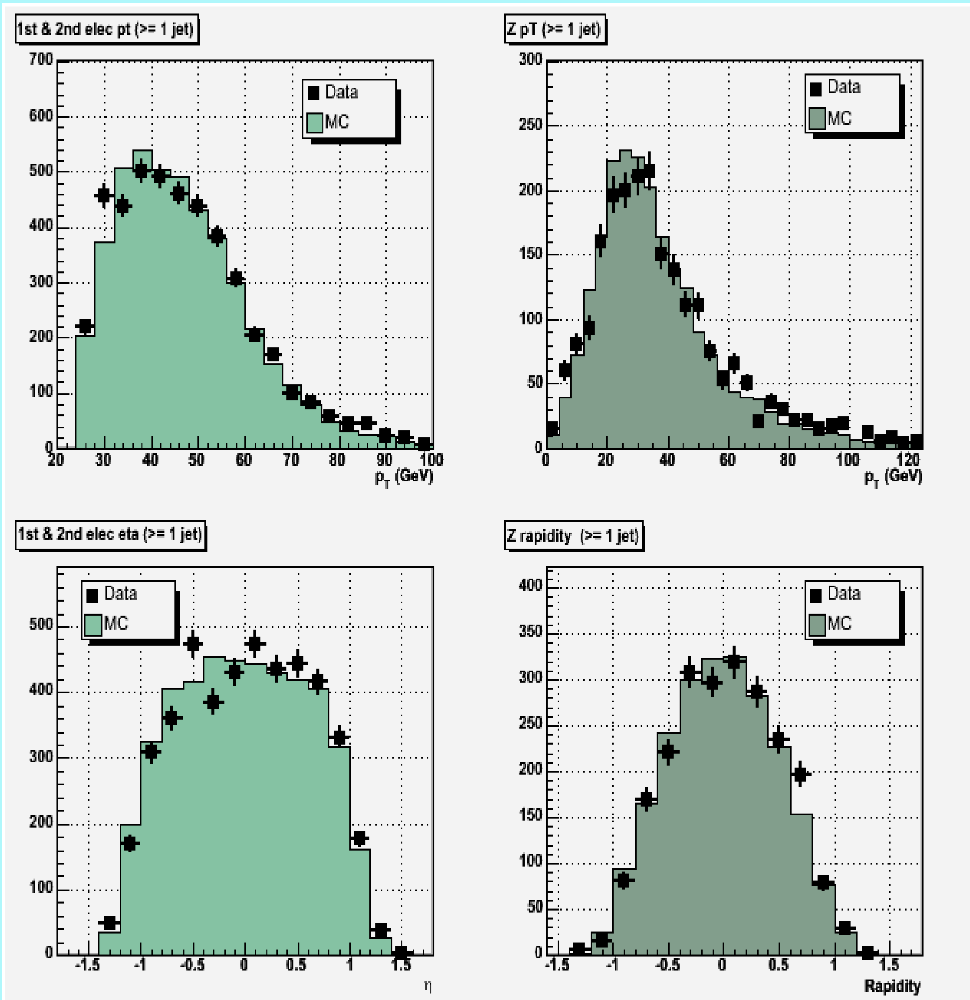




Mass = 91.02 GeV
Width = 4.03 GeV

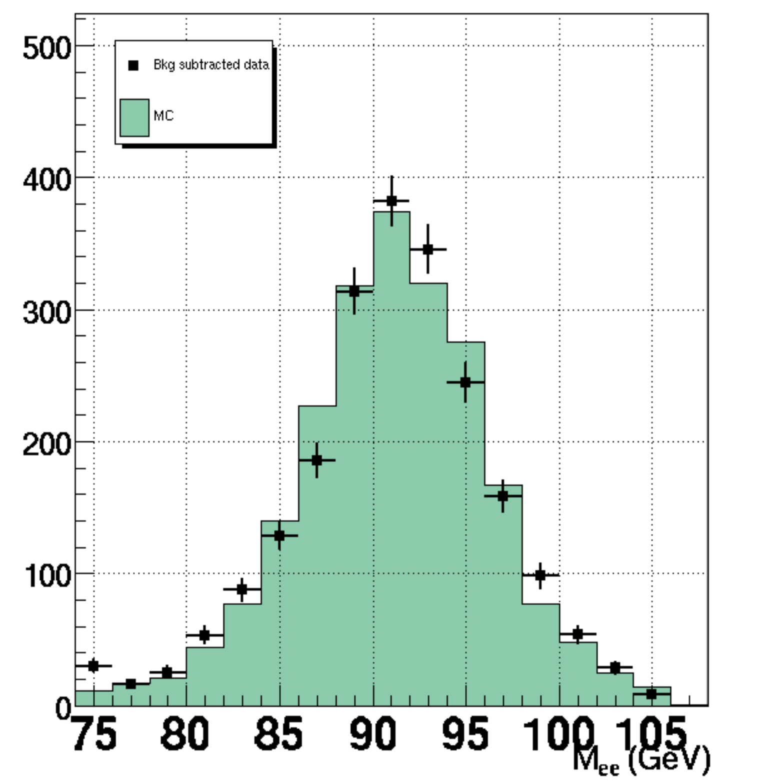
# Z(ee) + ≥1jet(s): Electrons and Zs

Sample size ≈ 1.6k events

MC = Zj Alpgen




Z peak

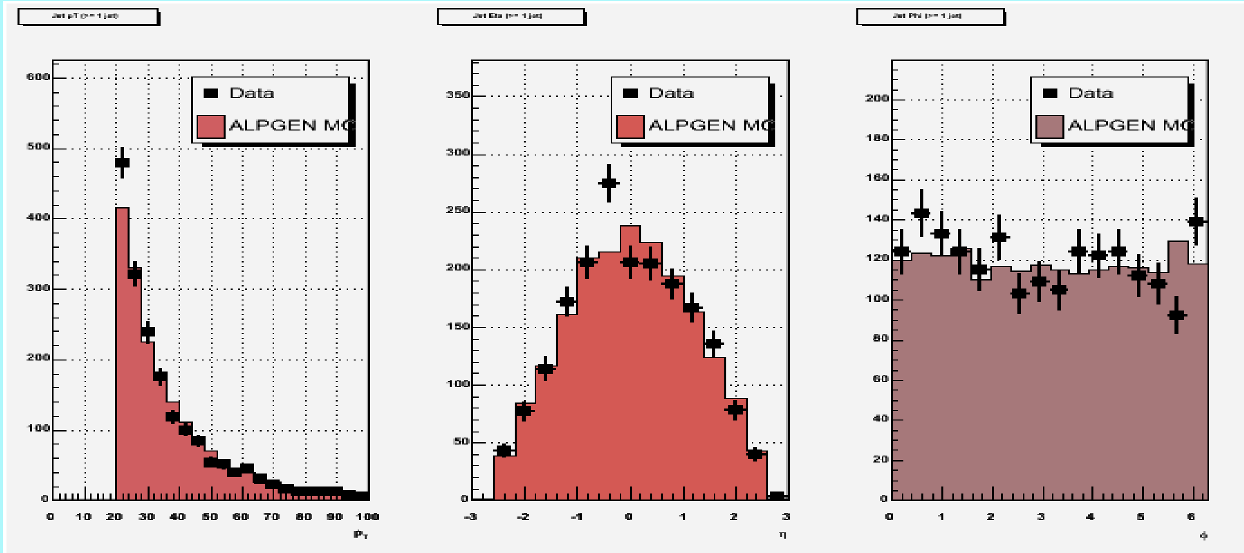



Mass = 91.40 GeV

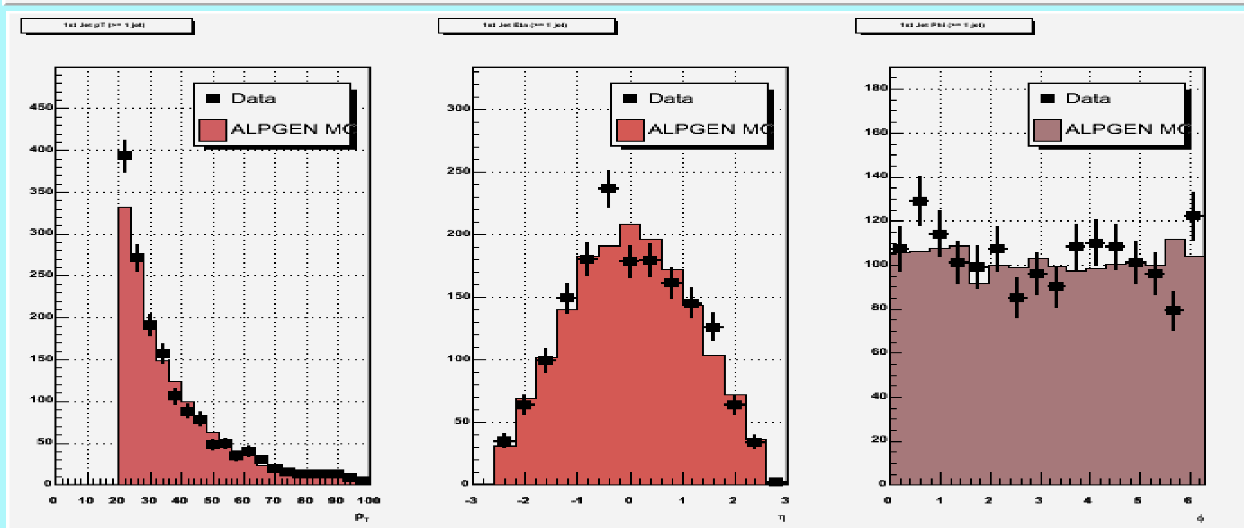
Width = 4.09 GeV

# Z(ee) + ≥1jet(s): Jets

All Jets



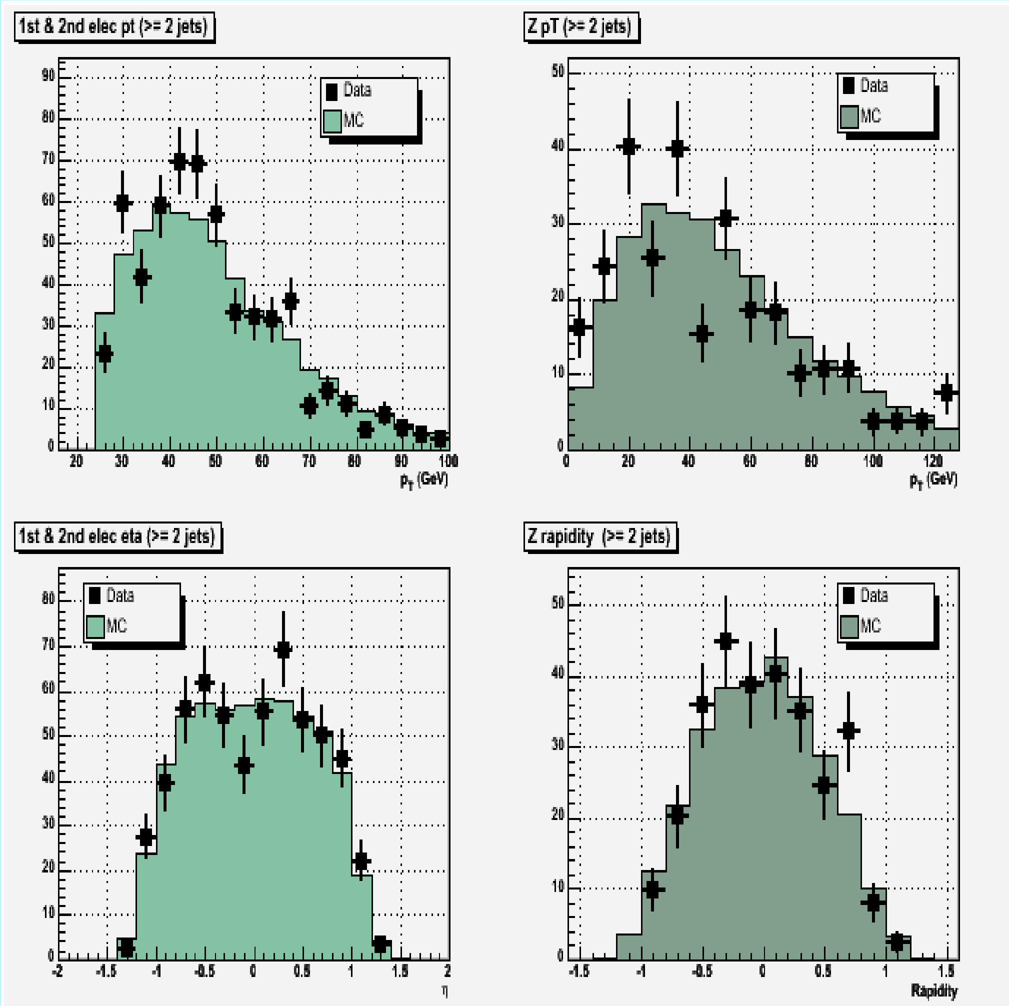

Lead Jet



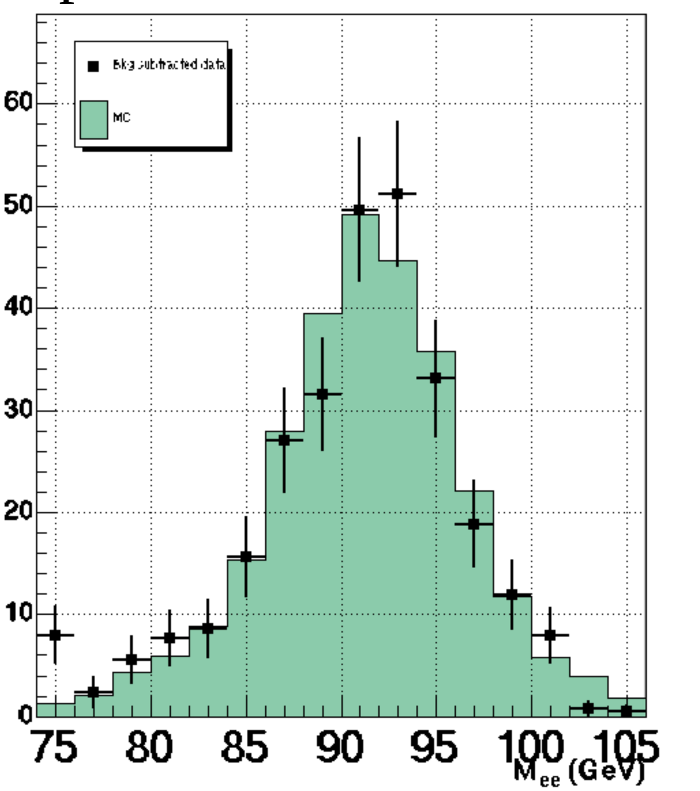
# Z(ee) + ≥2jet(s): Electrons and Zs

Sample size ≈ 200 events

MC = Zjj Alpgen




Z peak



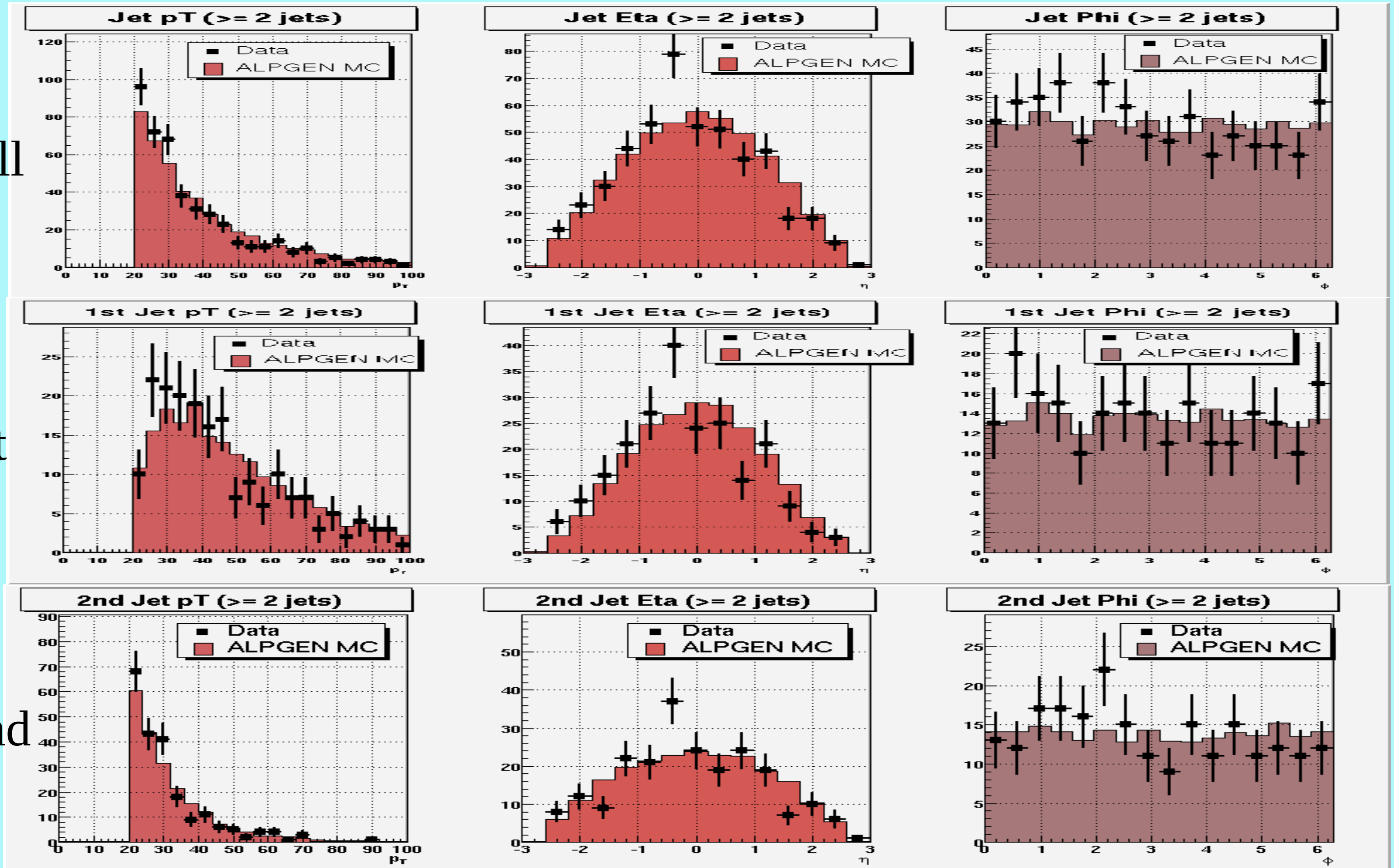

Mass = 91.47 GeV
Width = 3.72 GeV

# Z(ee) + ≥2jet(s): Jets

All

1st

2nd



# Unsmearing

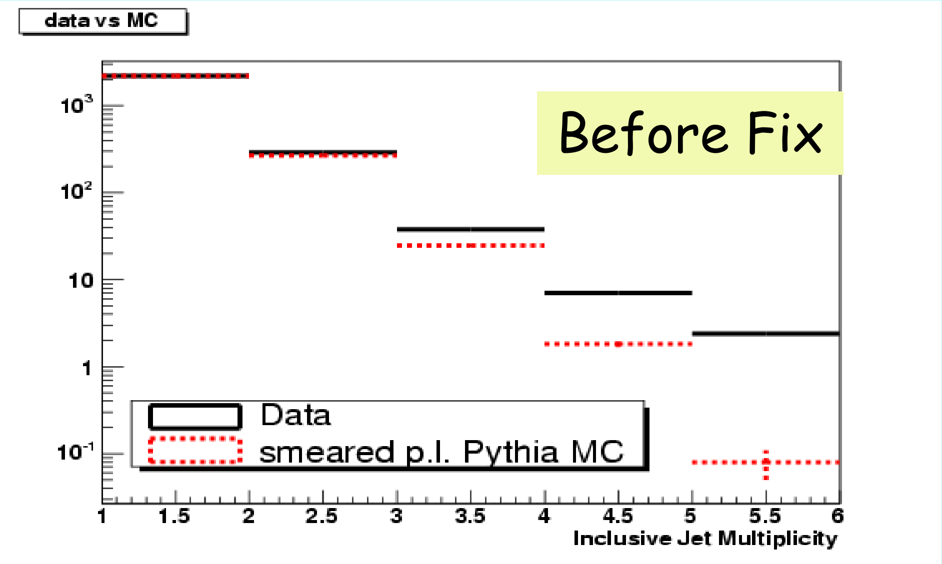
# Concept

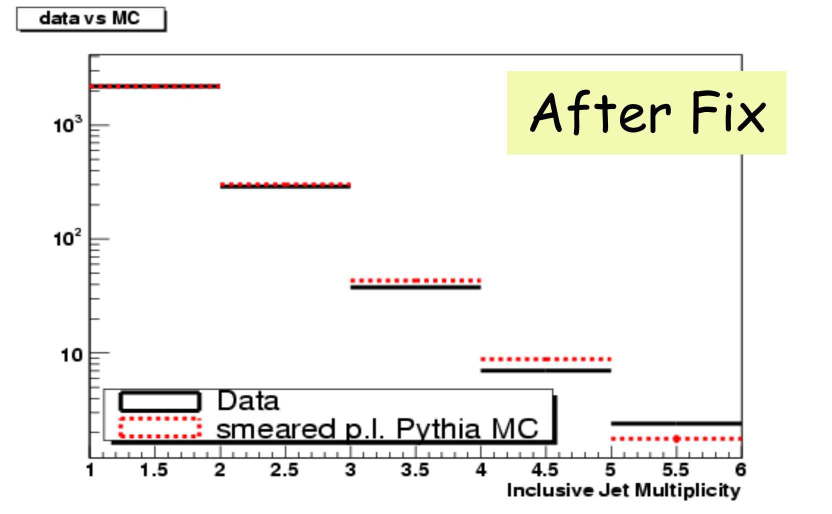
- In order to determine particle level cross sections, we unsmear the measured data jet multiplicities
- We use a Z+j Pythia sample (2-to-2 processes) which only contains particle level jets (no detector simulation)
- To be able to compare to data we smear the jet pT and also apply the jet reco/ID efficiencies
- In MC we ...
  - ... get the inclusive jet multiplicity histogram for particle level jets with pT>20GeV and |eta_phys|<2.5
  - ... get the inclusive jet multiplicity histogram for particle level jets with smeared pT>20GeV and |eta_phys|<2.5 (plus application of jet reco/ID efficiencies)
  - ... take the ratio between the two histograms to get the unsmearing coefficients
  - ... apply the unsmearing & jet reco/ID coefficients to the measured data jet multiplicities in data to unsmear

# 'Fixing' Pythia

Comparing the inclusive jet multiplicities for the smeared+Jet reco/id p.l. MC with data, shows disagreement at higher jet multi-plicities.

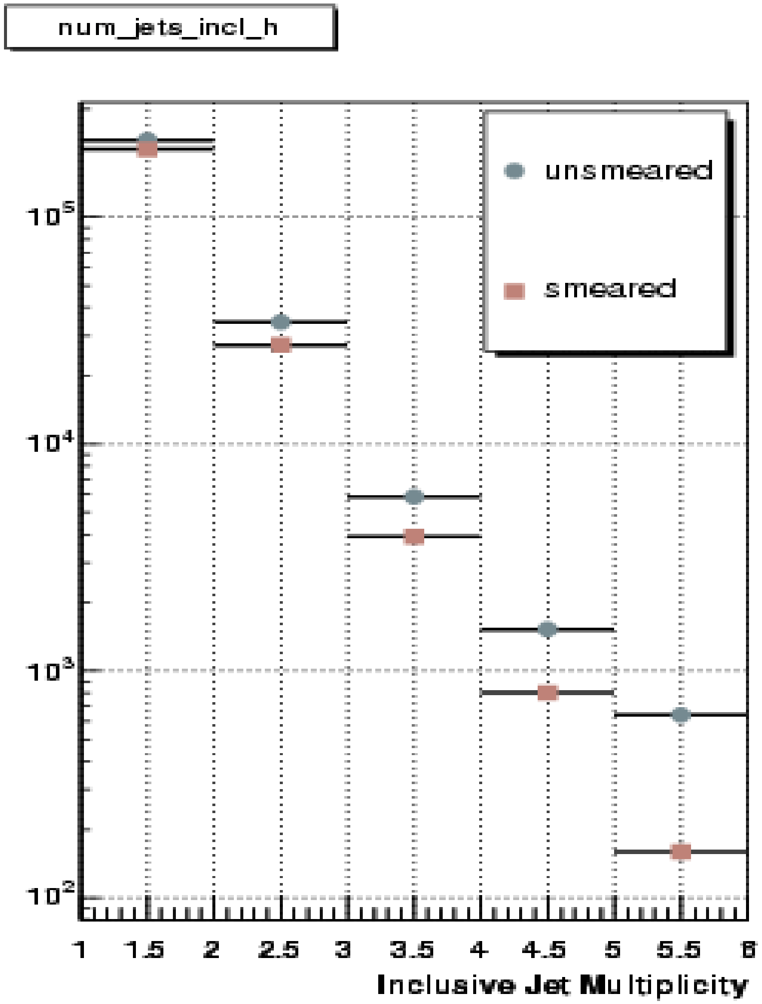
Pythia doesn't include higher order contributions at the hard scatter level.

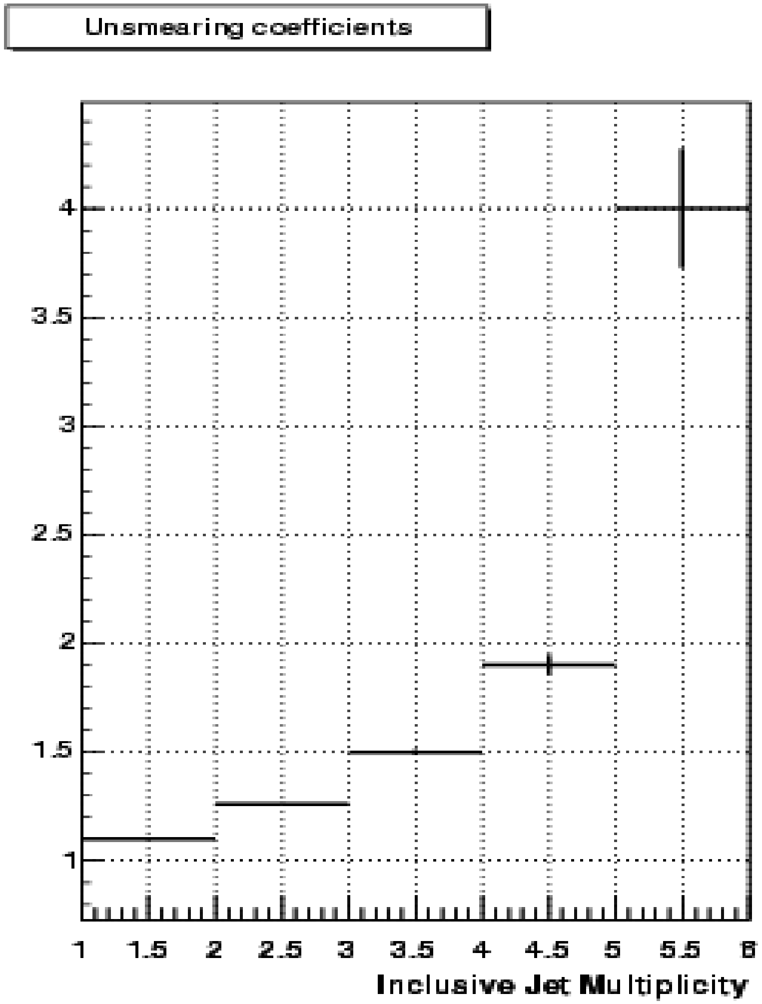



We apply the ratio between data and MC as a correction to 'fix' Pythia.

# Unsmearing Coefficients

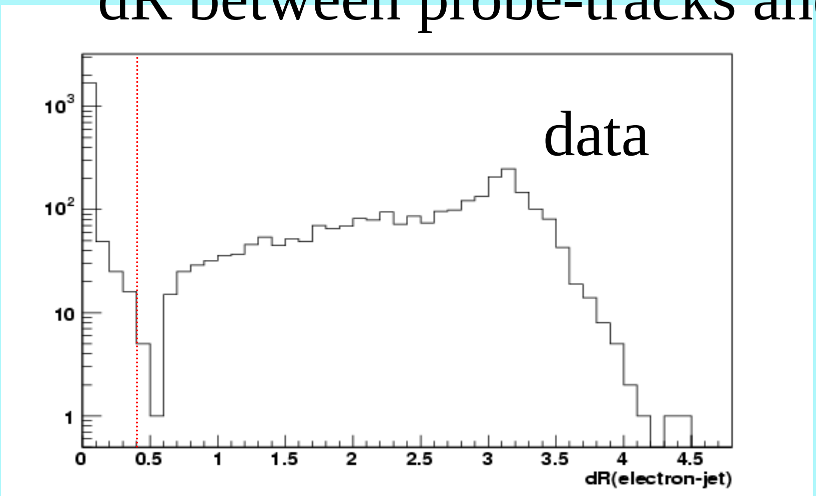


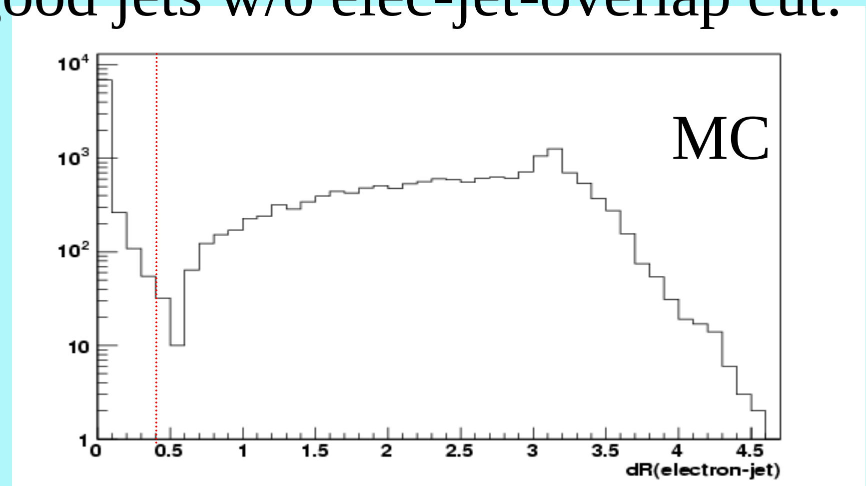



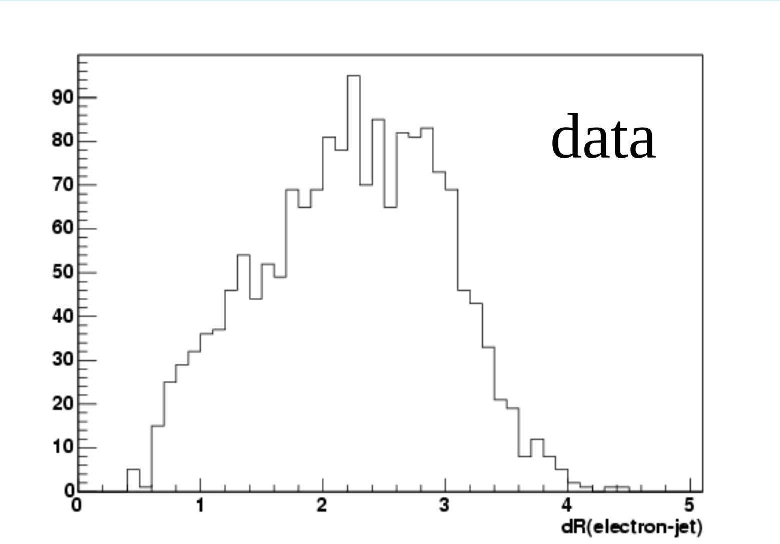
# Electron-Jet-Overlap Correction

# dR(Electrons - Jets)

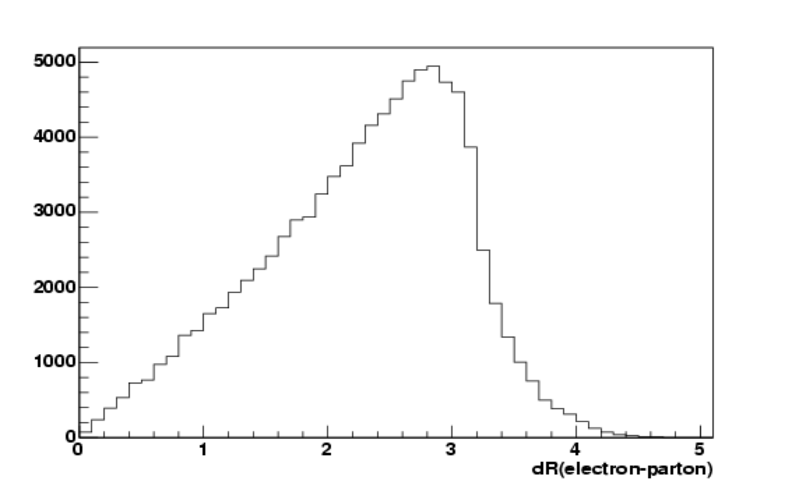
dR between probe-tracks and good jets w/o elec-jet-overlap cut:




with elec-jet-overlap cut




dR between generated elecs and partons

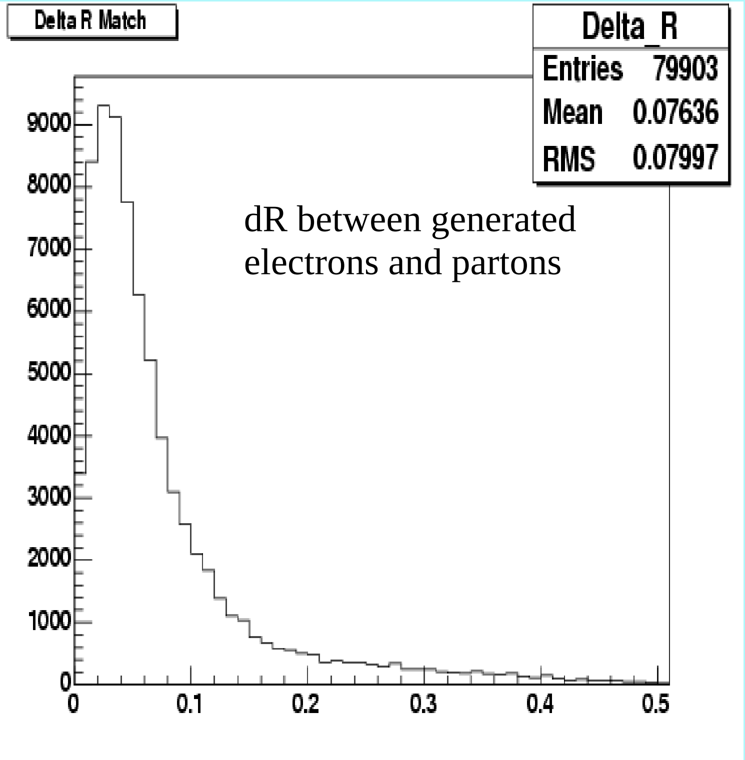
# Correction Factors

- We correct for real jets that are removed by elec-jet-overlap cut:

$$\frac{\text{Incl. parton multipl. for all partons}}{\text{Inlc. Parton multipl. for partons outside of dR cone}}$$

- We derive corrections using dR=0.4 and dR=0.7 and take the middle value (position resolution)

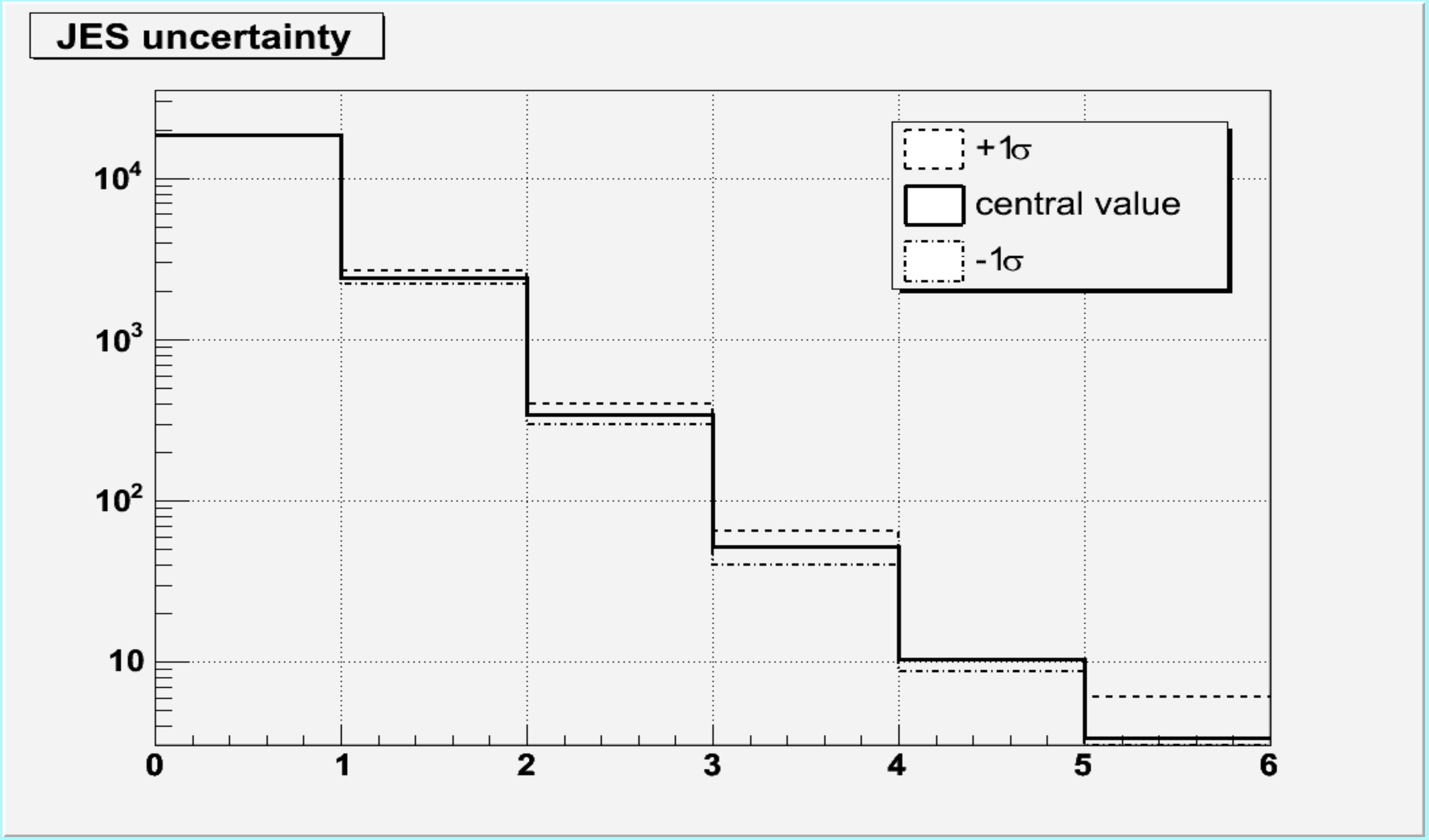
| Jet Mult | Coefficient |
|---|---|
| 1 | 1.059±0.028 |
| 2 | 1.075±0.041 |
| 3 | 1.092±0.054 |
| 4 | 1.109±0.067 |
| 5 | 1.125±0.077 |



# Systematics

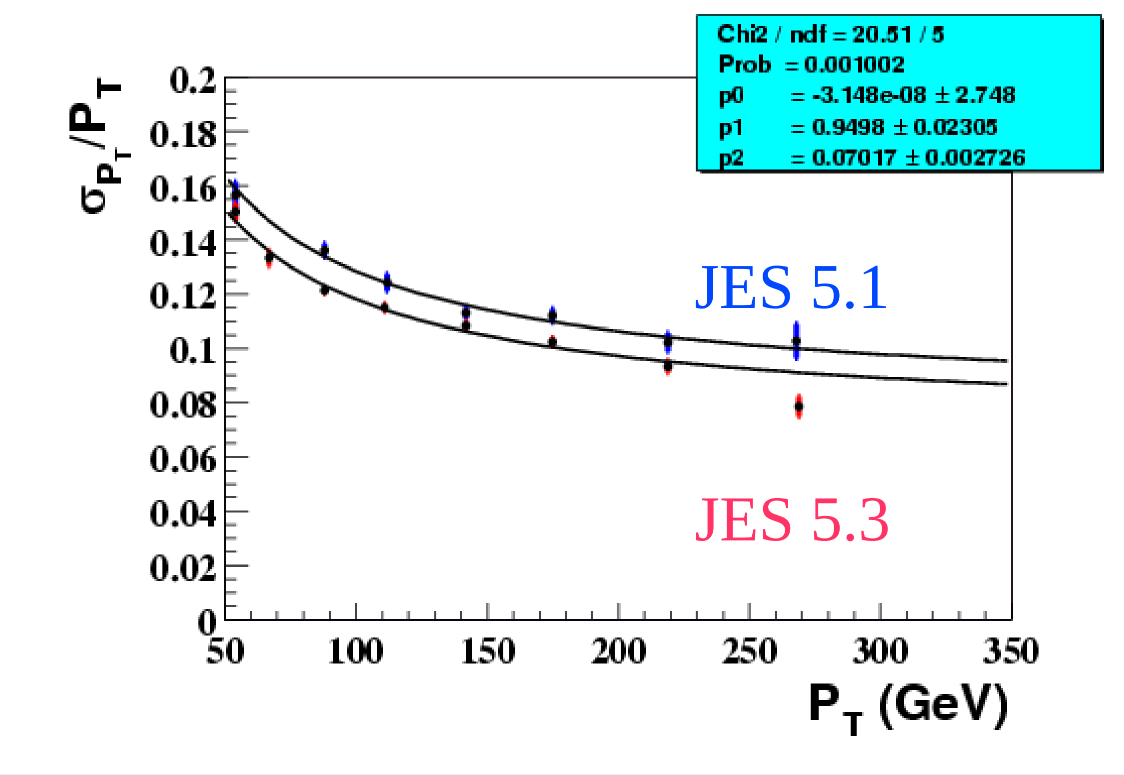
# JES Systematic Error

- We vary the JES (5.3) by +-1sigma:
  corrected jet pT = uncorrected jet pT x (JES correction +- JES error)



# Syst. Error of Cross Section Unfolding

- Jet reco/ID errors: statistics, MET (see previous slides)
- Jet resolution: need to account for the difference between JES 5.0 and JES 5.3




Difference is 5% over the whole range.
We assign 10%.

# Other systematics

- Electron-Jet-Overlap: Error = difference between the middle value and the dR=0.4(0.7) values
- Efficiencies: systematics are estimated using the **event based** efficiencies for trigger, EMreco/ID, and EM-Track efficiencies (systematics quoted in chapters 5.1.1-5.1.3

# Jet Promotion study

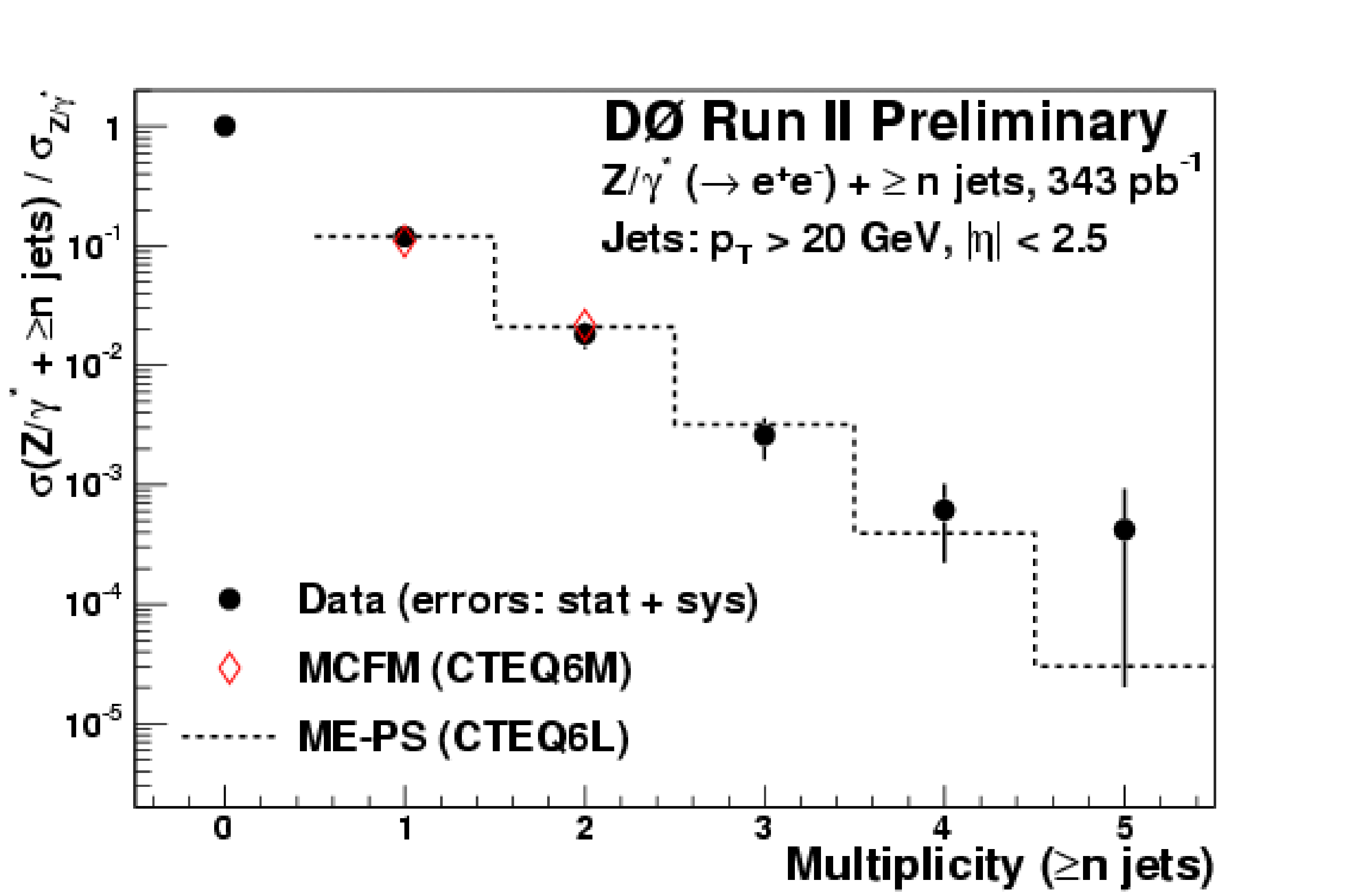
- Jet Promotion = gaining additional jets from multiple interactions within the same beam crossing
- We compare jet multiplicities for events that have exactly one reco'd P.V. with events that have at least two reco'd P.V.'s

| Jet Multiplicity | 1 P.V. | >= 2 P.V. |
|---|---|---|
| 0 | 5,900 | 5,900 |
| 1 | 705 | 696 |
| 2 | 92 | 97 |
| 3 | 11 | 16 |
| 4 | 3 | 1 |
| 5 | 1 | 1 |

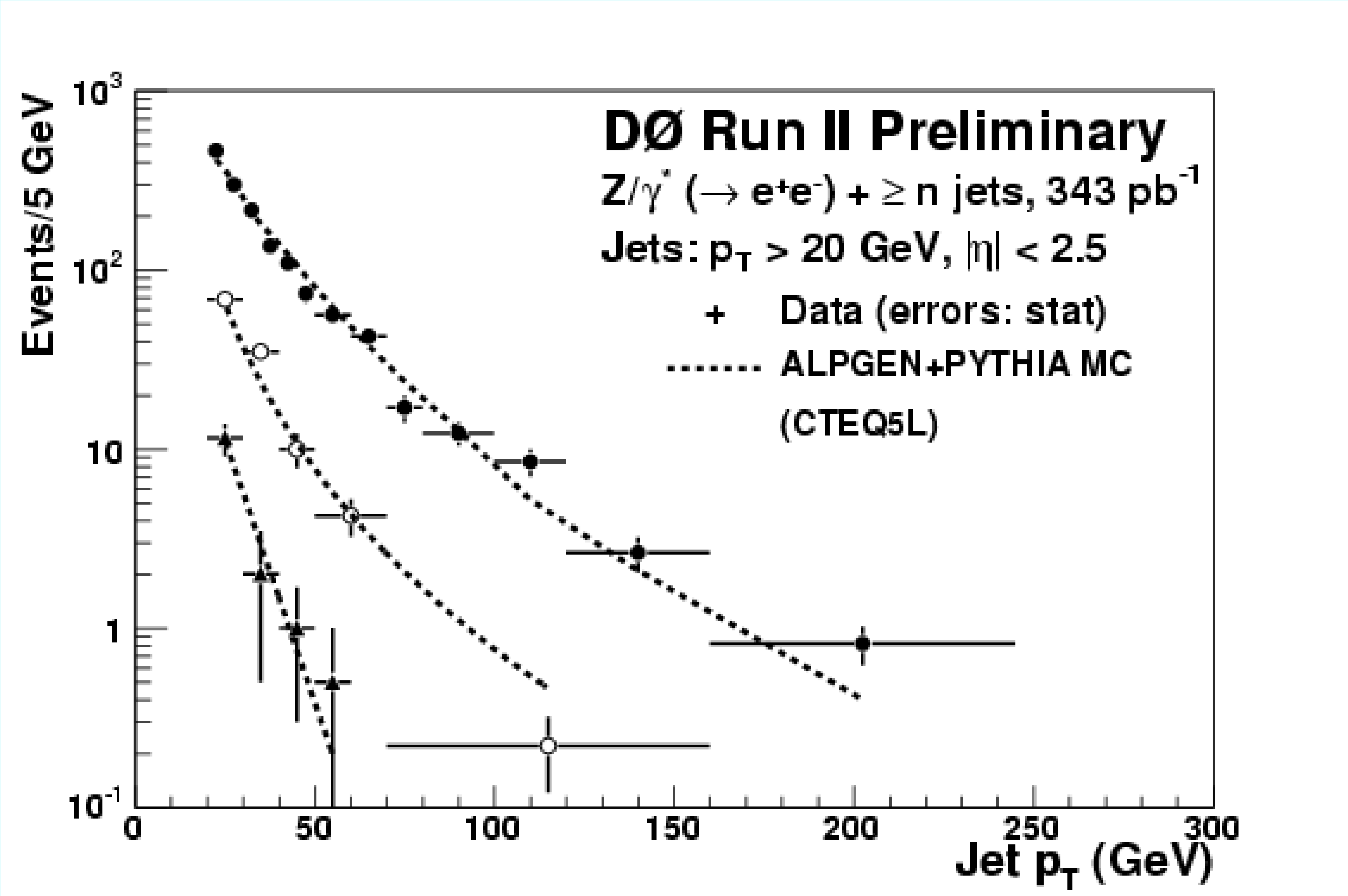
- Jet promotion effect is small since the discrepancy between the two samples is within statistical errors

# Z(ee) + ≥n Jet cross sections

# Cross Section Ratios



# Jet $P_T$ Spectra



# To Do List for Publication

- Use DØ's final Z inclusive measurement
- Study physics backgrounds
- Finalize the Jet Reco/Id Efficiency + Errors + Note
- Generate a large ME-PS sample (MADGRAPH up to 5 jets) at particle and detector level
- Use ME-PS sample for unsmearing
- Add JES error error band to Jet Pt spectra
- Complete/fine tune the systematic uncertainties
- Calculate ratios Z+$\geq$njet / Z+$\geq$(n-1)jet
  - Extract $\alpha_s$ (if time permits)?
- Quantify the comparison of Data-Theory/Theory